PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 5 : H04R 1/46, A61B 7/04	A1	(11) International Publication Number: WO 90/09083 (43) International Publication Date: 9 August 1990 (09.08.90)

(21) International Application Number: PCT/SE90/00066

(22) International Filing Date: 1 February 1990 (01.02.90)

(30) Priority data:
8900392-5 6 February 1989 (06.02.89) SE

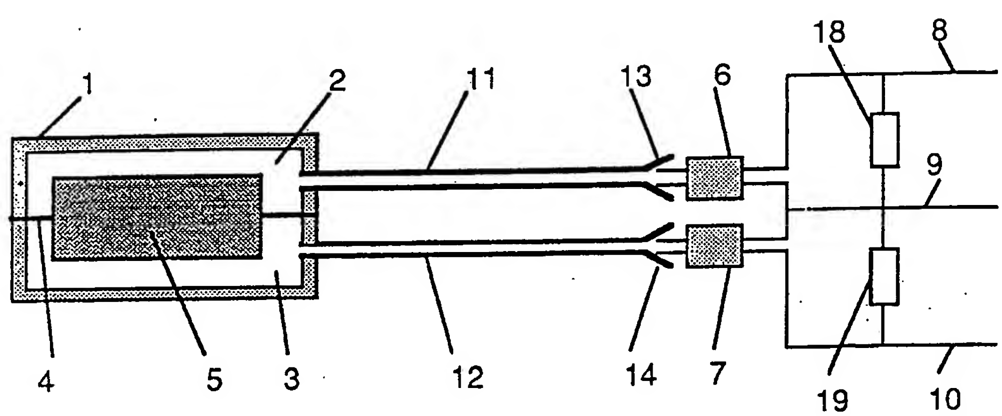
(71) Applicant *(for all designated States except US)*: HÖK INSTRUMENT AB [SE/SE]; Flottiljgatan 55, S-721 31 Västerås (SE).

(72) Inventor; and
(75) Inventor/Applicant *(for US only)* : HÖK, Bertil [SE/SE]; Sportfiskegatan 53, S-723 48 Västerås (SE).

(81) Designated States: AT (European patent), AU, BB, BE (European patent), BG, BR, CA, CH (European patent), DE (European patent), DK (European patent), ES (European patent), FR (European patent), GB (European patent), HU, IT (European patent), JP, KP, KR, LK, LU (European patent), MC, NL (European patent), SE (European patent), SU, US.

Published
With international search report.
In English translation (filed in Swedish).

(54) Title: MICROPHONE FOR DETECTING BODILY SOUNDS



(57) Abstract

Microphone for detecting bodily sounds consisting of a sealed and rigid housing (1), the inner of which is divided into at least two cavities (2, 3) separated by an elastic membrane (4) on which a mass element (5) is placed. The cavities are connected to pressure sensitive microphone elements (6, 7), e.g. capacitive electret elements (15) with built-in impedance converters (16) interconnected in a bridge configuration. The connection between the housing (1) and the microphone elements takes place either through leads in the form of tubing (11, 12) or by mounting the microphone elements (6, 7) through openings (20, 21) in the walls of the housing.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AT	Austria	ES	Spain	MG	Madagascar
AU	Australia	FI	Finland	ML	Mali
BB	Barbados	FR	France	MR	Mauritania
BE	Belgium	GA	Gabon	MW	Malawi
BF	Burkina Fasso	GB	United Kingdom	NL	Netherlands
BG	Bulgaria	HU	Hungary	NO	Norway
BJ	Benin	IT	Italy	RO	Romania
BR	Brazil	JP	Japan	SD	Sudan
CA	Canada	KP	Democratic People's Republic of Korea	SE	Sweden
CF	Central African Republic			SN	Senegal
CG	Congo	KR	Republic of Korea	SU	Soviet Union
CH	Switzerland	LI	Liechtenstein	TD	Chad
CM	Cameroon	LK	Sri Lanka	TG	Togo
DE	Germany, Federal Republic of	LU	Luxembourg	US	United States of America
DK	Denmark	MC	Monaco		

Microphone for detecting bodily sounds.

During auscultation and recording of bodily sounds, microphones are used for converting the acoustic signals into electric voltage variations which can be amplified and processed by well-known electronic technology. Recording and storage can be done using magnetic tape, and the signal can be presented acoustically by earphones, loudspeakers or visually on a cathode ray tube, a liquid crystal display, or the like.

A problem is that conventional microphones also pick up acoustic, mechanical, and electromagnetic interference to such a high degree that the recording of very weak bodily sounds often will have an unsatisfactory signal quality, the signal being sometimes completely masked by the noise.

There are two basically different solutions to this problem. One is to use a sensor, the output signal of which is proportional to the vibrations of the skin surface, and the mechanical impedance of which is matched to that of skin. Such a sensor can be built up as a sandwich structure of different layers. The active sensor layer is composed of a piezoelectric material, while the other layers give mechanical protection to the relatively sensitive piezoelectric layer, and provide an electrostatic shield against "hum" caused by the line voltage, and interference having other origin. This solution results in a relatively complex construction with high demands on precision and skilled labour in the assembly, which leads to a relatively expensive product which is difficult and costly to produce in large volume.

Another solution is to use a microphone set up consisting of two or more microphone elements connected in a bridge configuration, where each microphone picks up the bodily sounds through a housing which is either open against the skin, or connected to it via a thin membrane in contact with the skin. Strongly localized acoustic signals, such as the bodily sounds, will be picked up by the microphone bridge, whereas common incident sound will be suppressed. Such an arrangement will, however, require that the acoustic connection of the two microphones are equal in order to result in efficient suppression of noise. This is only partly accomplished in practice which means that suppression of airborne acoustic noise is limited.

In the present invention, this basic problem of noise suppression is solved without the disadvantages of the mentioned solutions. The invention can be said to make use of the same basic physical principle but in a design which makes mass production at low cost possible of a microphone with very good suppression of interference from different sources. Another important advantage with the present microphone is the simplicity in its use. In contrast to most alternative designs is does not require a tight seal against the skin and the sensor can be applied by adhesive tape or simply lying by its on weight on the skin. The invention is characterized by the enclosed claims and will in the following be described in connection to the enclosed drawings. Figure 1 shows the microphone according to the invention in one preferred embodiment, Figure 2 the deasign of a single microphone element. Figures 3 and 4, finally, shows alternative designs.

The microphone according to the invention consists, as is depicted in Figure 1, of a housing 1, the inner of which is a closed inner space in relation to the ambient. In reality, the sealing of this housing should be so tight that airborne acoustic signals in the ambient are not transmitted by an eventual leakage to the closed inner space. The material of the housing could be metallic or a polymer, and its walls should be rigid enough so that resonance vibrations in the audible frequency range do not appear. The inner of the housing 1 is divided into two cavities 2, 3 by an elastic membrane 4, which can consist of a thin foil of latex (natural rubber) silicone or another elastomer. A mass element 5 is placed on the membrane 4, advantageously made from a material having high density. When the housing 1 is vibrating, e g by bodily sounds that reach the skin surface on which the housing has been placed, the mass 5 will counteract against the vibratory movement by its inertia, and by the elasticity of the membrane 4. This leads to pressure variations of opposite sign of the gas (mostly air) inside the two cavities 2, 3. In figure 1, an accelerating motion downwards in the figure leads to a relative displacement of the mass 5 relative to to the housing 1 so that the upper cavity 2 will have a positive pressure, whereas the cavity 3 will have a negative pressure. Pressure sensitive microphone elements 6, 7 are connected to the cavities 2, 3 and convert the differential pressure variations in the cavities 2, 3 into electric voltage variations. In one embodiment of the invention the microphone elöements 6, 7 are each connected through leads 11, 12 in the form of tubing. This embodiment has the advantage that the housing 1 the membrane 4, the the mass 5 and the leads 11, 12 can be manufactured as a stand-alone unit which can be connected or disconnected to/from the microphone elements 6, 7 by connectors 13, 14. In their simplest form, the connectors 13, 14 can consist of tubing sections, one of which is slightly conical in shape, as depicted in

Figure 1. Other designs of e g lockable connectors using threads or bayonette principles, or the like, are, of course, possible.

The microphone elements 6, 7 are connected in a bridge configuration with two voltage supplying leads 8, 10 and one signal carrying lead 9. As described earlier such a bridge configuration gives suppression of noise incident on the elements in equal phase. This is the case for airborne acoustic noise, if the distance between the microphone elements is considerably smaller than the wavelength of the interfering acoustic wave.

The bridge configuration is especially suitable when capacitive electret elements with built-in impedance converters are used as microphone elements. One such element is schematically depicted in Figure 2. The microphone element consists of a capacitor 15, the plate separation, and thereby the capacitance of which, varies according to the pressure. A polarized electret material is inserted in the capacitor 15 which gives rise to a charge displacement corresponding to the capacitance variations, and in turn, voltage variations between the connections of the capacitor. These voltage variations are transferred to the gate of a field effect transistor 16, the main function of which is to provide an output signal having a low output impedance, allowing useful lengths of the signal carrying lead 9. Microphone elements with small physical dimensions and with built-in impedance converters according to this description are commercially available in a variety of detailed designs and are mass produced for use in telephone appliances, tape recorders etc.

It is also possible to compensate for individual variations in sensitivity between different microphone elements 6, 7 by connecting resistors or capacitors 18,19 in parallel or in series with the microphone elements.

The housing 1 is advantageously cylindrical with a diameter of 15-50 mm and having a height of 5 - 25 mm. If the requirements on distortion-free signal transmission are high, the length of the leads should be considerably less than the sound wavelength of the highest frequency one wishes to record. If the leads are longer, standing waves will occur, which will redistribute the frequency spectrum of the signal to frequencies where the well-known resonance conditions for standing waves are fulfilled. In many applications, e g patient monitoring, this phenomenon of distortion is unimportant, and leads up to several meters can be tolerated. The inner diameter of the leads should be as small as possible, since their volume will add to the

volume of the cavities 2, 3. The smaller the added volume, the bigger pressure variation will be for a given movement of the membrane 4 and the mass 5. If long leads 11, 12 are necessary, the inner diameter can often be chosen so that the gas flow resistance of the leads gives an optimal attenuation of the abovementioned resonance phenomenon. For example, with a lead length of 100 cm, efficient attenuation, and thereby a distortion-free signal transmission, can be obtained with an inner diameter of approximately 1.0 mm. The material of the leads 11, 12 can be a relatively flexible polymer, such as poly vinyl chloride with an added softener. the leads 11, 12 can also be built into one common polymer jacket.

Another mechanical resonance phenomenon appears as a result of the mass 5 and the elasticity of the membrane 4, in combination with the compliance of the closed air volume of the cavitiies 2, 3, eventually with the added air volume of the leads 11, 12. This mechanical resonance frequency should either be chosen higher or lower than that of the actual bodily sounds, if the demands on good signal quality is high.

An advantage with the connectors 13, 14 used for non-permanent connection between the housing and the microphone elements is that the dimensions, shape of the housing, and the length of the leads can be adapted to the anatomy of the individual patient and to the application by interchanging the housing and the leads. This is important, since the variations between different patient groups are large. In certain designs, it could be an advantage to have the microphone elements 6, 7 built in an amplifyer case, having also the electrical connections 8, 9, 10 incorporated in the case.

In connections where the signal quality is of utmost importance, one wishes to minimize the closed volumes 2, 3 and the length of the leads 11, 12. In this case the design shown in Figure 3 is suitable. The figure shows a microphone with many common characteristics with that of Figure 1. The microphone consists of a housing 1, the inner of which is divided into two cavities 2, 3 by a membrane 4 and a mass element 5. Two microphone elements 6, 7 are connected to the cavities 2 and 3. In this case the connection takes place by mounting the microphone elements 6, 7 directly on the housing 1 by means of two holes 20, 21 in the wall of the housing. Similarly to that shown in Figure 1, the microphone elements are electrically interconnected by bridge configuration with two leads 8, 10 for voltage supply, and one lead 9 for signal transmission.

In Figure 4, another design of the microphone according to the

invention is described. It has similarities to those of Figure 1 and 3 since it consists of a housing, in this case made from three bonded plates 22, 23, 24 of single crystalline silicon. The inner of the housing is divided into two cavities 25, 26 through a membrane 27, and a mass element 28 which have been fabricated by etching from one of the silicon plates.

The airgap 29 between the plate 22 and the mass 28 constitutes a capacitor, the capacitance of which is dependent on the width of the airgap, which in turn varies according to vibratory motion of the housing caused by the mass 28 and the elasticity of the membrane 27. The variations of the capacitance give rise to a charge diplacement in a thin layer of an electret material applied to the gate region of a field effect transistor, which has been integrated by photolithography and diffusion of dopants according to well-known technology into the silicon plate 22. The field effect transistor consists of a conducting channel 33 the conductance of which can be modulated from the gate electrode by "source" and "drain" electrodes 31, 32. The conductance of the channel 33 is modulated by the charge distribution on the gate, whereby impedance conversion is performed analogously to that described in connection with Figure 2.

The design of Figure 4 shows that the microphone design can be integrated on a small number of silicon plates. By using fabrication technology known from the manufacture of integrated circuits, it is possible to produce the microphone according to the invention at a very low cost. The manufacture consists of a small number of process steps such as deposition of electret material, dopants, metal layers for connections, etching of cavities, and then finally bonding.

The microphone according to the invention can be varied in many ways within the framework of the following claims.

Claims.

1. Microphone for detecting bodily sounds characterized in a tight and rigid housing (1) the inner of which is divided into at least two cavities (2, 3) sparated by at least one membrane (4) having at least one mass element (5) applied, and that to at least one of the cavities (2, 3), at least one pressure sensitive microphone element (6, 7) is connected.

2. Microphone according to claim 1 characterized in that each of the cavities (2,3) is connected to one microphone element (6,7), whereby these are connected in a bridge configuration with supplying leads (8, 10) and at least one signal transmitting lead (9) in such a way that varying pressure differences between the cavities (2, 3) give rise to electric voltage variations on the signal transmitting lead (9), whereas common pressure variations occurring simultaneously in the cavities (2, 3) do not give rise to sucg voltage variations.

3. Microphone according to claim 1 characterized in that the microphone elements (6,7) consist of capacitive electret elements (15) with built-in impedance converters (16).

4. Microphone according to claim 1 characterized int that the microphone elements (6, 7) are connected to their respective cavities (2, 3) through leads (11, 12), preferably in the form of flexible tubing.

5. Microphone according to claim 1 characterized in that the microphone elements (6,7) are connected to their respective cavities (2, 3) through openings (20, 21) in the walls of the housing (1).

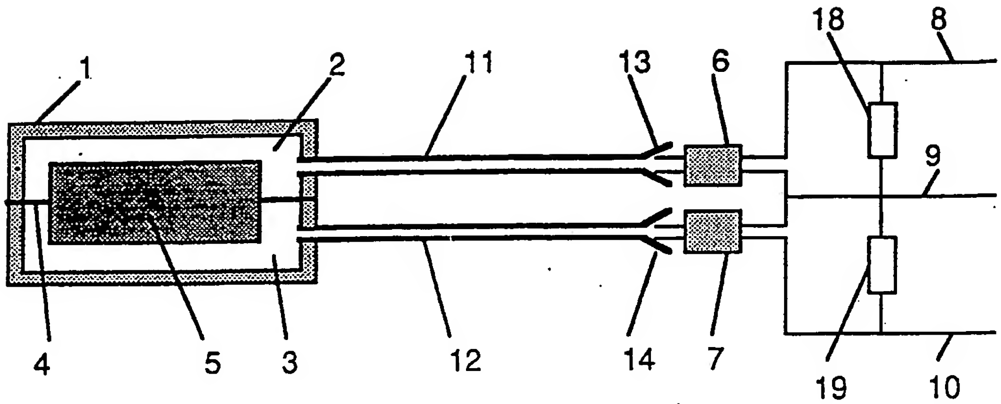
6. Microphone according to claim 1 characterized int that the mass (5) and the membrane (4) elasticity and the cavity (2, 3) compliance do not exhibit any mechanical resonance in the frequency region of the bodily sounds.

7. Microphone according to claim 1 and 4 characterized in that the inner diameter of the leads (11, 12) are chosen so that resonances in the housing (1) or the leads (11, 12) are attenuated by the flow resistance of the leads (11, 12).

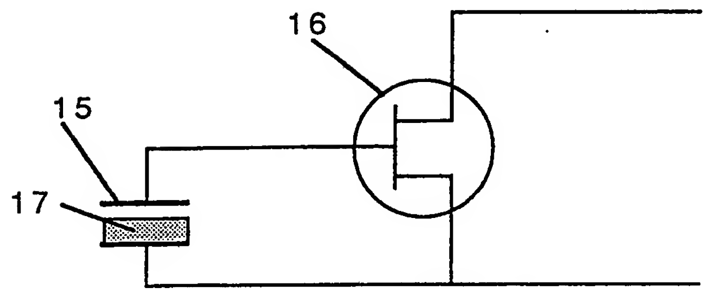
8. Microphone according to claim 1 and 4 characterized in at least one connector (13, 14) for non-permanent connection of the housing (1) with the microphone elements (6, 7).

9. Microphone according to claim 1 characterized in that the mass (28), the membrane (27), and the microphone element (29) are integrated in a single crystalline silicon structure by etching, surface deposition and bonding of a small number of silicon crystals (22, 23, 24).

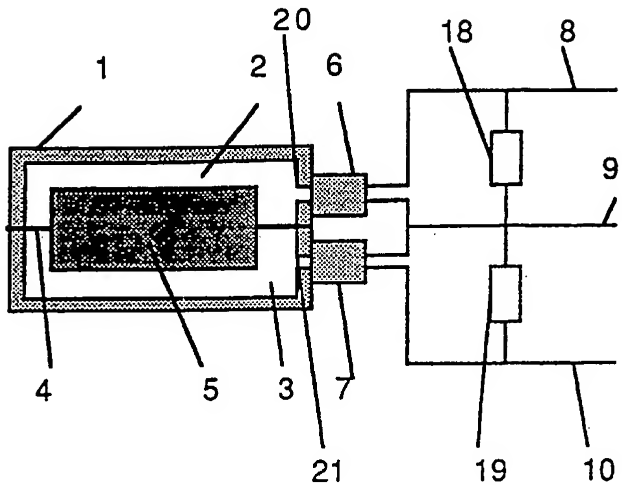
10. Microphone according to claim 1 and 2 characterized in that at least one resistive or capacitive impedance element (18, 19) is connected in series or in parallel with at least one of the microphone element (6, 7).



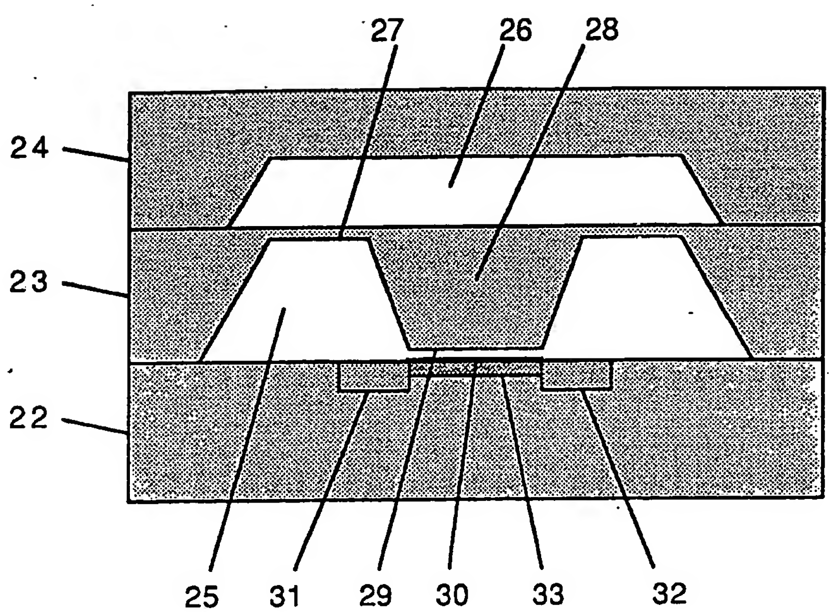
Figur 1



Figur 2



Figur 3



Figur 4

INTERNATIONAL SEARCH REPORT

International Application No PCT/SE 90/00066

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC5: H 04 R 1/46, A 61 B 7/04

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
IPC5	H 04 R, A 61 B

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

SE,DK,FI,NO classes as above

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category *	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
A	SE, A, 320760 (THE MARCONI CO., LTD) 16 February 1970, see the whole document --	1-10
A	Derwent's abstract No. F28 16 D/23, SU 759 860, publ. week 8123 --	1-10

----

* Special categories of cited documents: [10]
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
18th April 1990	1990 -04- 23
International Searching Authority	**Signature of Authorized Officer**
SWEDISH PATENT OFFICE	SVEN FENGER-KROG Sven Fenger-Krog

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO. PCT/SE 90/00066

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
SE-A- 320760	70-02-16	NONE	